Electrical Propetries in Discotic Liquid Crystal Hexahexyl-oxytriphenylene

Ryo Azumai, Masanori Ozaki, and Katsumi Yoshino

Department of Electronic Engineering, Graduate School of Engineering,
Osaka University,
2-1 Yamada-oka, Suita, Osaka 565-0871, Japan
Tel: +81-6-6879-7759, Fax: +81-6-6879-7774
E-mail: ozaki@ele.eng.osaka-u.ac.jp

Introduction

In the discotic liquid crystal, because of the existence of a columnar structure, various anisotropy will appear in the discotic phase. [1-5] For example, Carrier generation and transport properties in discotic liquid crystal have been studied by means of a time-of-flight method. In this study, the anisotropy of electrical conductivity and carrier mobility have been estimated using two types of electrode configurations, that is, a sandwich and inter-digit electrode.

Experimental

2,3,6,7,10,11-hexahexyloxytriphenylene (HHOTP)was used in this study. Figure 1 shows molecular structure of HHOTP. This discotic liquid crystal was synthesized by the method already reported and purified by a column chromatography with chloroform/benzene (1/4) as eluent, and then recrystallized from acetone. [6]

The discotic phase of HHOTP appeared in the temperature range between 56 °C to 90 °C. The HHOTP sample was introduced by a capillary effect in sandwich cells composed of two parallel quartz plates. Two types of electrode configurations were used for the measurement of anisotropy. One has two indium tin oxide (ITO) electrodes on both substrates(sandwich cell). Another one has an inter-digit electrode on one substrate.(inter-digit cell)

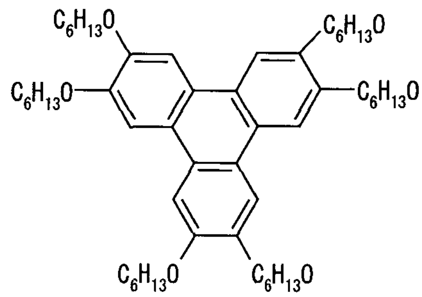

Figure 1. Molecular structure of HHOTP

The conductivity and mobility parallel and perpendicular to the column were measured utilizing the sandwich and inter-digit cells, respectively. By cooling from the isotropic phase, a columnar structure of molecular alignment perpendicular to the quartz plates was realized in the discotic phase, which was confirmed by the microscope observation. In the sandwich cell, the electric field is applied parallel to the columnar axis, while in the inter-digit cell, the field is perpendicular to the column. The carrier mobility was evaluated by a time-of-flight method [7] utilizing the third harmonics generation (THG) of Nd:YAG laser light(355nm) with 20ns in pulse width as an excitation light source.

Results

Figure 2 indicates temperature dependence of electrical conductivity in HHOTP. In this case, the measurement was carried out during the cooling stage with a cooling rate of 0.2℃/min. It is clearly shown in this figure that the conductivity in the direction parallel to the column is much larger than that of perpendicular direction in the columnar phase. Moreover, the difference of an activation energy in the discotic phase indicates that the conduction mechanism along the columnar structure is different from that of across to the columnar structure.

Figure 3 shows field dependence of the transient time for both positive and negative carriers. From this figure, it is found that the mobility for the positive carrier was much larger than that for the negative carrier.

In order to evaluate the mobility for the carrier migration perpendicular to the columnar axis, the inter-digit cell was used for the time-of-flight measurement. Figure 4 shows theoretical signal for the time-of- flight measurement with inter-digit electrode.

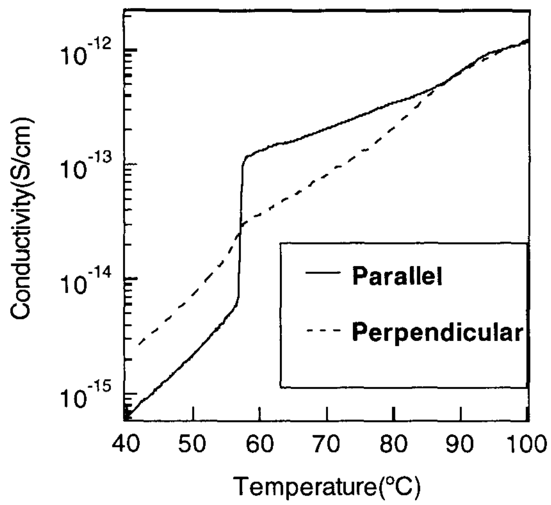

Figure 2. Temperature dependence of the conductivity of HHOTP

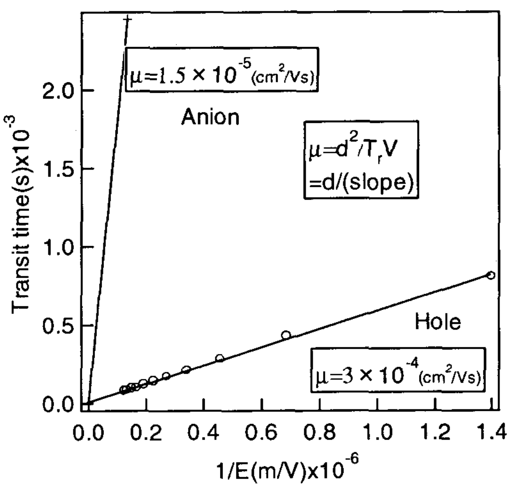

Figure 3. Field dependence of transit time

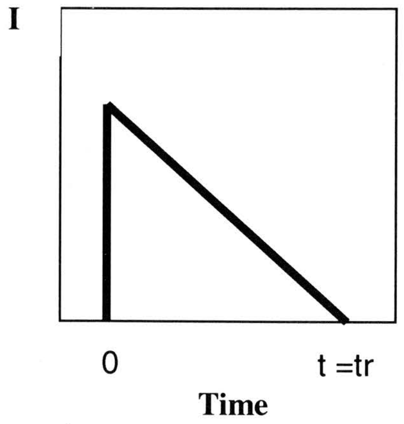

Figure 4. Theoretical signal of TOF signal with inter-digit electrode geometries.

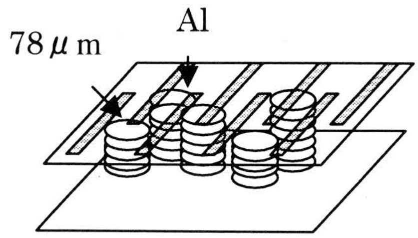

Figure 5. The structure of the cell with inter-digit electrode.

Figure 5 shows cell structure of inter-digit electrode. When the carrier density n_0 emerged by exciting light pulse is constant between electrodes and the carriers are traveling by the applied voltage at the velocity v_d, the total current density J(t), which drifts between electrodes at time t, is given as the integration of the charge carrier density [8]:

$$J(t) = \frac{e_0 n_0 V_d}{d} \int_{V_d t}^{d} dx = J_0 \left[1 - \frac{t}{t_d} \right]$$

where d is the distance between electrodes, J_0 is the initial current density at t=0 and t_d is the transit time of the carrier.

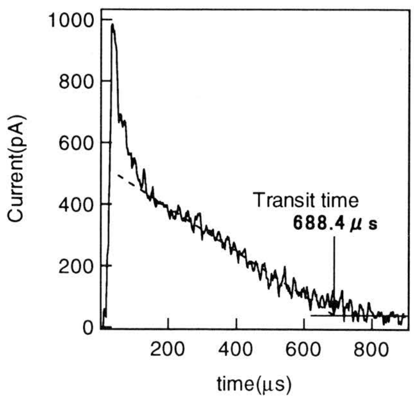

Figure 6. The experimental TOF signal of the cell with inter-digit electrode.

Figure 6 shows an experimental waveform of transient photocurrent in the inter-digit cell. From this transit time, we can estimated the mobility in the direction perpendicular to the columnar axis, which is smaller than that in the direction parallel to the columnar axis.

References

[1] W. F. Schmidt and A. O. Allen: J. Chem. Phys. **50** (1969) 5037

[2] R. M. Minday, L.O. Schmidt and H. T. Davis: J.Chem, Phys. **50** (1969) 1473

[3] D. Adam, W. Rokhildt and D. Haarer: Jpn. J. Appl. Phys. **35** (1996) 1826.

[4] D. Adam, F. Closs, T. Frey, D. Funhoff, D. Haarer, H. Rigsdorf, P. Schuhmacher and K. Siemensmeyer: Phys. Rev. Lett. **70** (1993) 457.

[5] K. Yoshino, H. Nakayama, M. Ozaki, M. Onoda, M. Hamaguti: Jpn.J.Appl Phys. **36**(1997)5183

[6] L. Y. Chiang, C. R. Safinya, N. A. Clark, K. S. Liang and A. N. Bloch: J. Chem. Soc. Chem. Commun. (1985) 695.

[7] K. Yoshino: IEEE Trans. Electr. Insul. **21** (1986) 999.

[8] W. F. Schmidt: *Liquid State Electronics of Insulating Liquid.* (Boca Raton, (1997) CRC Press).